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CONSUMPTIVE USE IN MUNICIPAL AND INDUSTRIAL AREAS

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IRRIGATION DIVISION

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Irrigation	46, 47, 48, 55, 56, 57, 67, 70, 71, 87, 88, 90, 91, 96, 97, 98, 99, 102 (Discussion: D-XXIII, D-3, D-7, D-11, D-19, D-25-K, D-29, D-17, D-30, D-38, D-40, D-44, D-47)
Power	48, 55, 56, 69, 71, 88, 96, 103 (Discussion: D-XXIII, D-2, D-3, D-7, D-11, D-19, D-25-K, D-17, D-30, D-38, D-40, D-44)
Sanitary Engineering	55, 56, 87, 91, 96 (Discussion: D-10, D-29, D-37)
Soil Mechanics and Foundations	43, 44, 48, 94, 102, 103 (Discussion: D-4, D-XXVIII, D-7, D-43, D-44)
Structural	42, 49, 51, 53, 54, 59, 61, 66, 89, 100, 103 (Discussion: D-5, D-3, D-8, D-16, D-23, D-13, D-21, D-24, D-25-K, D-32, D-17, D-33, D-34, D-39, D-42, D-37)
Surveying and Mapping	50, 52, 55, 60, 63, 65, 68
Waterways	41, 44, 45, 50, 56, 57, 70, 71, 96 (Discussion: D-XXVII, D-9, D-8, D-19, D-27, D-28)

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PAPERS

CONSUMPTIVE USE IN MUNICIPAL AND
INDUSTRIAL AREAS

BY GEORGE B. GLEASON,¹ ASSOC. M. ASCE

SYNOPSIS

A typical survey to determine the consumptive use of water in municipal and industrial areas is described in this paper. In order to determine a fair distribution of water rights in the Raymond Basin Area, Pasadena, Calif., an evaluation was made of the factors involved. The results of this study are presented, and the data is analyzed to emphasize points that may be of assistance in the planning and execution of similar surveys.

INTRODUCTION

Consumptive use of water in municipal and industrial areas includes transpiration and evaporation from lawns, shrubs, and trees; evaporation from bare surfaces; and the relatively very small increments evaporated in household and industrial uses or retained in industrial products. It does not include sewage, surface runoff, or water percolating beyond the root zone of the covering vegetation, all of which are or can be made available for re-use.

A municipality can be defined as that area devoted to residences, commercial and industrial establishments, churches, schools, parks, and cemeteries. Residential areas vary in their water consuming characteristics, the amount consumed depending primarily upon what part of the area is devoted to each of the several types of vegetation and what part to buildings, paved surfaces, and so on. Commercial areas also show a consumptive use, ranging from closely built-up centralized districts in which water-consuming vegetation is virtually nonexistent to scattered establishments in the suburbs around which there may still be considerable areas of lawns, shrubs, and trees.

SURVEY OF RAYMOND BASIN AREA

In connection with a suit for the adjudication of water rights,² brought by the City of Pasadena against other producers of water from the Raymond

NOTE.—Written comments are invited for publication; the last discussion should be submitted by May 1, 1951.

¹ Supervising Hydr. Engr., State of California, Division of Water Resources, Los Angeles, Calif.

² "City of Pasadena vs. City of Alhambra," No. Pasadena C-1323 in the Superior Court of the State of California, in and for the County of Los Angeles, February, 1939.

Basin Area in Los Angeles County, it was deemed necessary that the consumptive use within the basin be evaluated. The Division of Water Resources, Department of Public Works of the State of California made an investigation and report on the physical facts.

Cultural Classification of Area.—During 1938 and 1939 the City of Pasadena, as the first step in this investigation, completed a detailed survey of the culture of the area involved. Of the approximately 23,000 acres in the western unit of the area, nearly 17,000 acres (or about three fourths of the total) was devoted to urban types of culture. For purposes of the survey this urban culture was classified as follows: (1) Estates; (2) class A residential; (3) class B residential; (4) rural residential; (5) commercial; (6) semicommercial; (7) reservoir sites; (8) parks; (9) schools; and (10) streets. Although it is probable that there are no two lots that are identical in the relative proportions of buildings, driveways, lawns, shrubs, and trees, there is materially less variation between lots within each of the above classes than between those in different classes. The results disclosed by the survey are presented in the following tabulation:

Classification	Acreage	Classification	Acreage
Estates.....	2,604	Shrubs.....	4
Class A residential.....	2,167	Lawns and ornamental trees.....	63
Class B residential.....	3,170	Ornamental trees.....	1,481
Rural residential.....	765	Avocado and citrus.....	904
Commercial.....	193	Deciduous.....	294
Semicommercial.....	532	Vineyard.....	1,024
School.....	272	Nursery and truck.....	296
Park and cemetery.....	453	Vacant.....	2,252
Reservoir site.....	63	Brush.....	2,275
Streets.....	3,722	River wash.....	354
Lawns and shrubs.....	5		
		Total.....	22,893

The first ten classifications listed in this tabulation constitute urban culture. With the exception of commercial and streets, which were assumed to include no water-consuming vegetation, each of these classifications includes, in various proportions, vacant areas, buildings, driveways, lawns, shrubs, trees, and possibly other water-consuming vegetation. It was assumed that an accurate determination of the relative proportion of the area that was devoted to each type of culture on a few representative areas in each classification would provide a reliable basis for evaluating the acreage in each type on the whole urban area. The same assumption was applied to river wash areas that included areas of brush and bare sand and gravel. Table 1 presents a composite of the results obtained on the typical areas. Applying these percentages to the area of each urban classification as determined by the survey and adding the areas not included in those classes, the total acreage in each type of culture was obtained and is also listed in Table 1.

Unit Consumptive Use Values.—The next step in the evaluation of consumptive use was the assignment of unit values of consumptive use for each of the several types of culture covering the area. Prior to this considerable exper-

imental work had been carried on, having as its objective the evaluation of unit consumptive use values for agricultural crops and native vegetation. So far as could be determined, similar work on the types of vegetation that are peculiar to municipal development had been negligible. Because of this lack of information the City of Pasadena, in cooperation with the United States Department of Agriculture, carried out an extensive program of soil sampling for moisture determination throughout the period October, 1937, to October, 1939, and the State Division of Water Resources installed and operated an

TABLE 1.—CONSUMPTIVE USE SURVEY OF THE WESTERN UNIT OF
RAYMOND BASIN AREA

Type of Culture	Area in acres	CLASSIFICATION									Estimated consump- tive use in feet
		Estates	RESIDENTIAL			Semi- com- mercial	Res- ervoir site	Parks	Schools	River wash	
			Class A	Class B	Rural						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(a) NUMBER OF TYPICAL AREAS STUDIED											
		5	5	5	3	5	5	3	3	1	
(b) PERCENTAGE OF CLASSIFICATION DEVOTED TO SPECIFIC CULTURE											
Impervious	6,371	19	33	23	14	43	43	17	28	...	0.50
Lawn and shrubs	1,894	19	23	18	12	7	4	28	25	...	3.00
Lawn and trees	1,533	20	16	13	5	3	0	30	0	...	3.33
Shrubs	831	7	10	8	9	6	24	11	4	...	...
Vacant	3,617	4	6	19	33	23	18	9	38	...	1.50
Ornamental trees	2,607	20	5	10	12	8	11	5	5	...	2.33
Deciduous	977	8	4	8	12	8	...	...	...	...	1.75
Citrus	1,098	3	3	1	1	2	...	...	...	...	2.00
Nursery and truck	312	...	...	...	2	...	...	...	...	...	3.00
Sand and gravel	206	...	...	...	...	...	...	...	...	58	0.50
Brush	2,423	...	...	...	...	...	...	...	...	42	1.67
Vineyard	1,024	...	...	...	...	...	...	...	...	...	1.67
TOTAL	22,893	100	100	100	100	100	100	100	100	100	

experimental plot consisting of eight tanks planted with lawn grass and surrounded by lawn. Water, including rainfall, was applied as required by the grass in the tanks, and the amount of water that was withdrawn as it accumulated in the bottom of the tanks was measured during the period from June, 1939, to July, 1945. Based on the experimental data so obtained, the unit values shown in Table 1 were assigned.

Combining the values presented in Table 1, unit values of annual consumptive use for each cultural classification were obtained and are listed as follows:

Cultural classification	Consumptive use in feet	Cultural classification	Consumptive use in feet
Estates.....	2.07	Reservoir sites.....	1.34
Class A residential.....	1.92	Park.....	2.40
Class B residential.....	1.88	Schools.....	1.63
Rural residential.....	1.78	River wash.....	0.99
Semicommercial.....	1.32		

The commercial classification was assumed to consume 6 in. Applying these values to the acreages as listed in Table 1 resulted in an estimated total consumptive use for the western unit of Raymond Basin Area equal to 36,166 acre-ft.

Subsurface Outflow.—In the Raymond Basin study the recognized principle that the hydrologic equation must balance was utilized to evaluate the subsurface outflow across Raymond fault, the lower boundary of the ground-water basin. Each of the items of supply and disposal other than the subsurface outflow was independently estimated in the manner of the following derivation:

Item	Quantity (acre-feet)
Water entering area:	
Precipitation.....	40,810
Inflow.....	11,650
Import.....	3,480
Water coming from storage in basin.....	5,810
Subtotal.....	61,750
Water leaving area on surface:	
Surface outflow.....	8,090
Export.....	14,630
Consumptive use.....	36,170
Subtotal.....	58,890
Subsurface outflow.....	2,860

Of the items appearing in the above derivation, inflow, outflow, import, and export were for the most part measured. The estimate of water coming from storage in the basin was based on measured changes in water table elevation at numerous and fairly well-distributed wells and also on specific yield values established by earlier detailed studies of the Division of Water Resources.³ The number and distribution of precipitation records was adequate.

No detailed independent estimate of the subsurface outflow appeared to be feasible at the time of the study, but general geological considerations indicated that the derived value was reasonable. Assuming that all values used in its derivation other than consumptive use were substantially correct, it follows that the value of over-all consumptive use was also substantially correct. It does not necessarily follow that the unit values presented in Table 1 are exact.

ANALYSIS OF RESULTS

Analyses of evaporation from soils indicate that the unit consumptive use value of 0.50 ft, arbitrarily assigned to impervious areas, may be high. Assuming that the true unit value is 0.30 ft, the consumptive use from the impervious area would be reduced by 1,274 acre-ft. Evidence available indicates that

³ "South Coastal Basin Investigation, Geology and Ground Water Storage Capacity of Valley Fill," *Bulletin No. 45*, State of California, Dept. of Public Works, Div. of Water Resources, 1934.

deciduous culture consumes more water than citrus culture. Assuming a unit value of 2.25 ft for deciduous culture results in an increase of 488 acre-ft., leaving 786 acre-ft to be accounted for if the over-all consumption from the area is to remain unchanged. An increase of a little more than $\frac{1}{16}$ ft in the unit values assigned to the three types of water-consuming culture that are peculiar to urban development (lawns and shrubs, lawns and trees, and ornamental trees) would accomplish the purpose. It is doubtful that unit values that are applicable to large areas can be established experimentally within such close limits. However, each of the values used in the hydrologic equation is subject to some error, so the desirability of independently evaluating, with the greatest possible accuracy, consumptive use, as well as each of the other factors, is apparent. Experimental data relating to unit consumptive use values for the types of culture that are peculiar to urban development is evidently limited to that obtained in connection with the Raymond Basin study. More work along this line is justified.

The effect of changes in culture on the supply of water required is of especial interest in areas that overlie ground-water basins of large capacity and in which rapid and extensive urban development is under way or anticipated. The paving of streets and the installation of sewers tend to increase the outflow. On the other hand the consumptive use may decrease. The weighted average unit consumptive use by a combination of the first four items of culture in Table 1 is 1.61 ft. This value is less than any of the unit values for the agricultural crops shown and also less than that for brush. It is greater than the values for vacant land and bare waste land.

To arrive at an approximation of the effect of future development on runoff, sewage production, and consumptive use in the western unit of the Raymond Basin Area, it was arbitrarily assumed that there would be no change in waste land along streams; but that ultimately 21% of the area would be devoted to streets, 5% would remain vacant, and the remainder would be devoted to municipal development, with each classification proportional to its 1939 acreage, as shown in Table 1. Under these conditions it is estimated that runoff would increase by about 2,800 acre ft over the 1939 values and that sewage production would increase by about 4,600 acre-ft but that consumptive use would decrease by about 300 acre-ft. The study further indicated that percolation to the ground water from precipitation and irrigation would increase under these conditions by about 2,200 acre-ft.

It was further estimated that the change from natural culture to that of 1939 resulted in an increase of about 3,400 acre-ft in runoff, an increase of about 8,100 acre-ft in sewage production, a decrease of about 2,300 acre-ft in consumptive use, and an increase of about 8,200 acre-ft, in percolation to the ground water from precipitation and irrigation.

The foregoing estimates indicate that existing urban culture in the Raymond Basin Area has decreased rather than increased consumptive use and has increased deep percolation to the ground water. On the other hand, it has materially increased surface runoff and the production of sewage. Whether or not all the effects would be comparable elsewhere depends not only upon the type of development but also upon the similarity of climate. Consumptive use by

native vegetation is directly related to the amount of precipitation available, and consumptive use by all vegetation is related to temperature. Average annual precipitation on the western unit of Raymond Basin Area ranges from 18 to 25 in. Where precipitation averages much greater than this, it is probable that the reduction in consumptive use resulting from urban development would be greater than the value estimated. Where precipitation is much less, it is possible that urban development might increase rather than decrease the consumptive use. During the period from June, 1939, to September, 1940, in which the lawn grass tanks were operated, the temperature at the plot ranged from 54.8° F in February to 75.2° F in July, 1940, and averaged 64.1° F during the year from July 1, 1939, to June 30, 1940. Had the temperatures been higher, the unit values presented in Table 1 would have been greater, and vice versa.

CONCLUSIONS

When considering consumptive use by urban development, each area presents its own problem. Whether or not in a particular case a culture survey as detailed as that outlined in this paper would be justified would depend upon the nature of the study. However, the value of more such surveys and further experimental work, with a view to more definitely establishing unit values for the various types of culture involved, cannot be questioned.